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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

Road Research Laboratory

REPORT FOR THE MINISTRY OF HOME SECURITY

THE VELOCITY OF SMALL BOMB FRAGMENTS

SUMMARY

Comparison of the penetration into timber of actual bomb fragments with that of projectiles fired from the micro-fragment gun in the laboratory shows that at 50 ft. from the bomb, average bomb-fragments weighing 53 milligrams, have a velocity of the order of 2000 ft./sec. In making this comparison, allowance has been made for the shape of the particles using the empirical method used by Poncelet, The difference between the probable initial velocity and the striking velocity at 50 ft. from the bomb appears to be due to the considerable drop in velocity over this distance produced by air resistance. Outside this radius, only velocities of from 2000 ft./sec. downwards need to be considered for particles smaller than 53 milligrams. This conclusion renders the problem of protection against such fragments much more hopeful of solution.

Correlation between bomb tests and laboratory penetration experiments

To simulate the action of very small bomb-fragments, laboratory methods have been devised for projecting small steel particles of standard size - 3/32-in. ball bearings, weighing 53 milligrams - at velocities ranging from 1500 to 4000 ft./sec. and a large number of tests at these velocities have been made on various materials.

The materials included three samples of red deal taken from targets used at Shoeburyness to receive fragments from an exploding bomb, it has thus been possible to correlate the laboratory work with full-scale tests. In the Shoeburyness tests, the targets were erected at 25 ft. and 50 ft. from a German 250 kg. bomb. After the bomb had been exploded, a sample was taken from each target. The penetration and mass of each fragment were measured at Forest Products Research Laboratory and the results for the target 50 ft. from the bomb are shown in Fig. 1. The scatter of the points in Fig. 1 is large, but it should be remembered that in addition to the mass, several other variables, including the velocity of the particle and its shape affect the penetration of the fragments. The general trend of the points can however be seen. The average laboratory penetration results obtained with the 3/32-in. ball bearing moving at various measured speeds are given in Table 1 and have also been plotted in Fig. 1, the measured velocity being indicated against each point.

/Table 1

14

143 a/d

143a/p

Table 1

Penetration of micro-fragment gun projectile into red deal (5 rings/in.)

Velocity of fragment (ft./sec.)	Penetration (mm.)
1350	16.7
1600	21.7
1750	24.2

Many of the usual formulae for the penetration of projectiles, such as that of Poncelet, give the penetration as proportional to the "shape-factor", M/A, of the projectile, M being the mass and A the projected area of the projectile. It has therefore been assumed that the penetration of bomb-fragments, moving with the same velocity, into a target of given resistance per unit area, is also proportion to the "shape-factor" of the fragments. A sphere has a "shape-factor" of $3.28\ M^{0.33}$ in milligram-millimetre units; while that for the actual bomb fragments was found to be $2.0\ M^{0.22}$; and on this theory the penetration of a sphere weighing 53 milligrams should be 2.6 times as great as the penetration of a bomb-fragment of equal mass.

The bomb-penetration tests showed that a fragment weighing 53 milligrams penetrated something of the order of 10 mm., and the considerations of shape outlined above show that a sphere of the same velocity and mass would penetrated about 26 mm. The estimated velocity of a sphere giving this penetration is about 1900 ft./sec. and similarly the estimated velocity of a fragment penetrating 13 mm. into the timber is about 2250 ft./sec. The penetration of actual bomb fragments weighing 53 milligrams is, however, rather uncertain, and until further data are available, it is impossible to form a very accurate estimate of the velocity by this method, but the conclusion is that bomb-fragments of similar size to the standard ball have a maximum velocity of about 2000 ft./sec. at 50 ft. from the bomb.

Further evidence, though of slight value, has recently been obtained from a few experiments performed in collaboration with Professor Zuckermann. Standard micro-gun projectiles were fired at a velocity of 2000 ft./sec. at fleshy tissue. The damage caused was much in excess of that expected from experience of wounds caused by bomb-splinters of this size.

Effect of air resistance on the velocity of small particles

It is believed that initially velocities comparable with those of the blast wave will be imparted to most fragments, irrespective of size. From the measured velocity of the larger fragments, which will not be greatly affected by air resistance at the distance of measurement, and from photographs of exploding charges, this is believed to be of the order of 5000 to 10,000 ft./sec. The effect of air-resistance has therefore been examined to see whether this will account for the low velocities of small fragments observed at 50 ft. from the bomb.

Aerodynamic resistance at supersonic speeds is given by the equation:-

$$R = C_D A \rho v^2 \quad (1)$$

where R is the resistance to motion,
A is the projected area of the fragment, normal to the direction of motion,
ρ is the density of air,
v is the velocity of the fragment
and C_D is a constant, called the ballistic coefficient.

If M is the mass of the fragment and a its deceleration, then

$$Ma = R = C_D A \rho v^2$$

$$\therefore \quad M\frac{dv}{dt} = C_D A \rho v^2$$

$$\text{Now } dt = \frac{ds}{v}$$

$$\therefore \quad M dv = C_D A \rho v^2 \frac{ds}{v}$$

$$\text{or } \log \frac{v_0}{v} = \frac{C_D A}{M} \rho s. \quad (2)$$

where s is the distance travelled,
and v_0 is the initial velocity.

Recently Prosser and Young * have determined the coefficient C_D for small models of various shapes by placing them in a wind-tunnel and measuring the drag. Using their values for C_D, the velocity-distance curves for a number of models of different shapes have been calculated and these are shown in Fig. 2. The effect of the shape is clearly shown. At 21 ft. the velocity of the star-shaped model is half its initial velocity and at 50 ft. it has dropped to one-fifth of its initial velocity. On the other hand, the velocity of a sphere that presents the same area to the air is still three-quarters of its initial velocity at 50 ft. (Curves 12 and 3 of Fig. 2). It is reasonable to assume that a smaller and more irregular fragment would be retarded more quickly. Thus assuming an initial velocity of from 5000 to 10,000 ft./sec., the fragments have a speed of only 1000 to 2000 ft./sec. when 50 ft. from the bomb.

This estimate agrees fairly well with the order of velocities deduced from the experimental work. If it be assumed that within a radius of 50 ft. from a bomb the danger from large splinters is high, whereas outside this radius many small targets will be hit only by smaller fragments, it would follow that body armour capable of withstanding small fragments moving with a velocity of 2000 ft./sec. would be of value. Incidentally on account of the "shape factor", the 55-milligram ball projected at 2000 ft./sec. in the laboratory tests is equivalent in its penetration to a considerably heavier bomb-fragment striking at this speed.

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* Prosser and Young: Report on the air resistance at supersonic speeds of various shaped models: R.C. 125.

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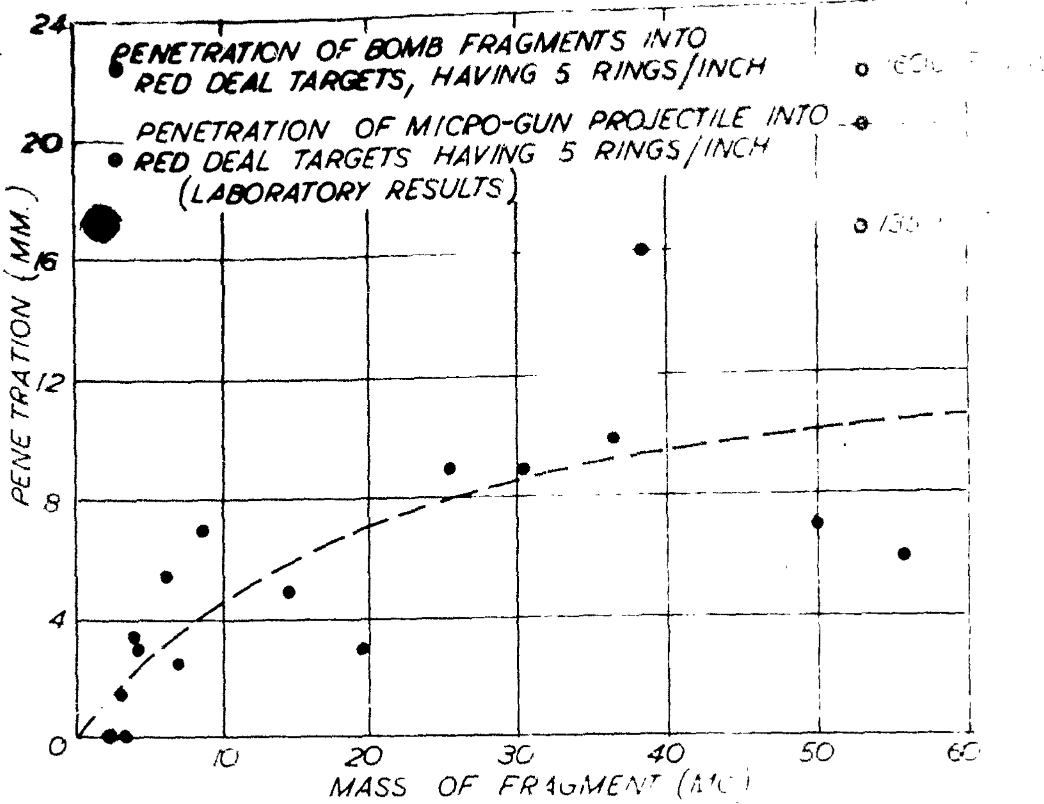

FIG 1. RELATION BETWEEN MASS OF FRAGMENTS AND PENETRATION INTO RED DEAL TARGETS 50 FT. FROM A GERMAN 250 KG. BOMB

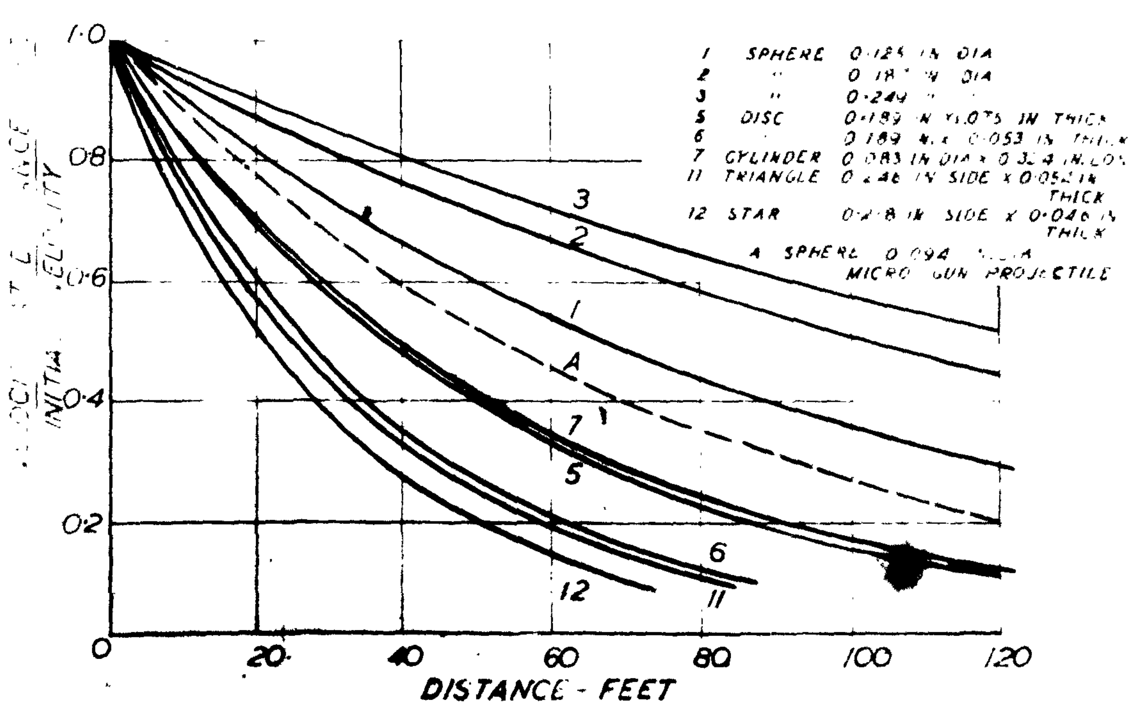

FIG 2. RELATION BETWEEN VELOCITY OF SMALL STEEL FRAGMENTS AND DISTANCE TRAVELLED FOR FRAGMENTS OF DIFFERENT SHAPES.

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